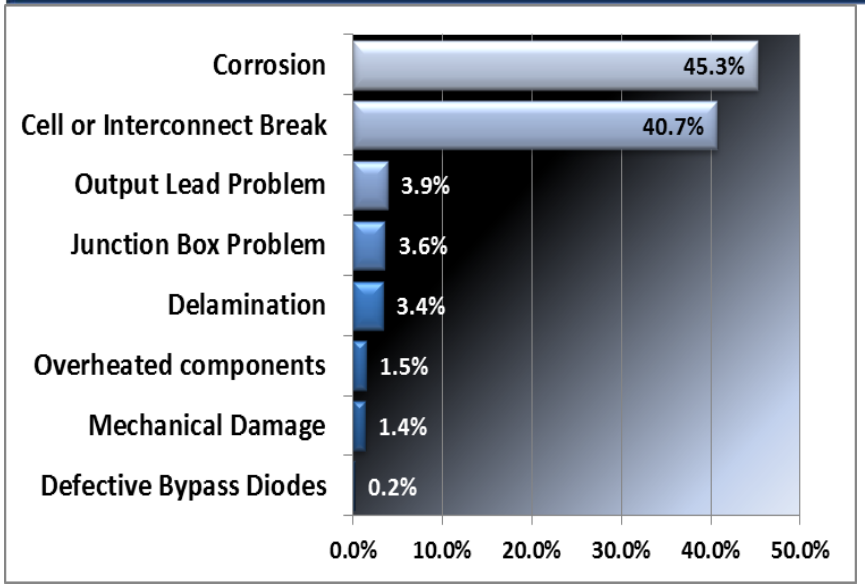
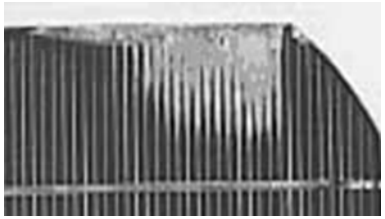
Lessons Learned From Flat Panel that can be applied to CPV

Lessons Learned – Flat Panel PV

Flat Panel Field Returns



Source: "Long Term Reliability of PV Modules", J.H. Wohlgemuth, D.W. Cunningham, A.M. Nguyen & J. Miller, BP Solar International



Source: "Commonly Observed Degradation in Field-Aged Photovoltaic Modules", M.A. Quintana[A], D.L. King[a], T.J. McMahon[b] and C.R. Osterwald; [a]Sandia National Laboratories, [b]National Renewable Energy Laboratories

Source: "Lifetime Performance of Crystalline Silicon PV Modules", Ewan D. Dunlap, European Commission, Joint Research Centre, Institute for Environment and Sustainability, Renewable Energies Unit

Reliability Issues to Consider for most PV Modules

- Loss of electrical connections (to cells, in junction box, or leads coming out of module)
- Delamination with subsequent moisture ingress
- Improper installation
- Glass Fracture
- Hot spots that are not adequately controlled by bypass diodes (hot spots can also be caused by loss of electrical connection, see above) or bypass diode failure
- Junction box failure

Source: "Photovoltaic-Reliability R&D toward a Solar-Powered World", Sarah Kurtz[a], Jennifer Granata[b], and Michael Quintana[b], [a]National Renewable Energy Laboratory, [b]Sandia National Laboratories

Lessons Learned – Flat Panel PV

Carrisa Plains – Brown EVA or Something Else?

Source: "Improved boost mirror for Low-Concentration Photovoltaic Power Systems, David Nelson Wells, Consultant

Statement of Problem: A field installation of 5.2MW rapidly degraded to 3.0MW

1988 ca Root Cause: Using Low-Concentration mirrored light created higher concentration of UV and temperature which then caused the EVA to degrade and turn yellow or brown.

1988 ca Solution: Add UV blockers to glass and EVA to absorb UV and avoid the EVA degradation. Cerium was added to glass to block the UV. Unknown at the time Cerium also causes solarization of glass (reduction in the transmission of the glass) which in of itself was a degradation mechanism.

2002 ca Root Cause: Initial degradation caused by light induced degradation (LID) from boron-oxygen couplets (specific to solar cell manufacturer). Further degradation caused by Isc degradation above 700 nm not in the UV region.

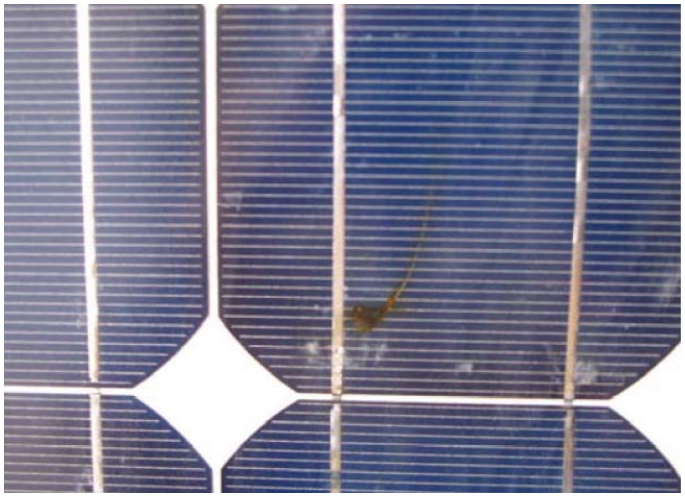
2002 ca Solution: Solar cell manufacturers have learned about how to reduce LID but reducing the oxygen content of the silicon and other techniques. Several other solutions have been implemented to reduce other degradation mechanisms in Crystalline Silicon Solar Cells.

Lesson Learned: Know *RIGHT* root cause to avoid solving the *WRONG* problem

Lessons Learned – Flat Panel PV

More Power = More Heat – 2 types of Hot Spots

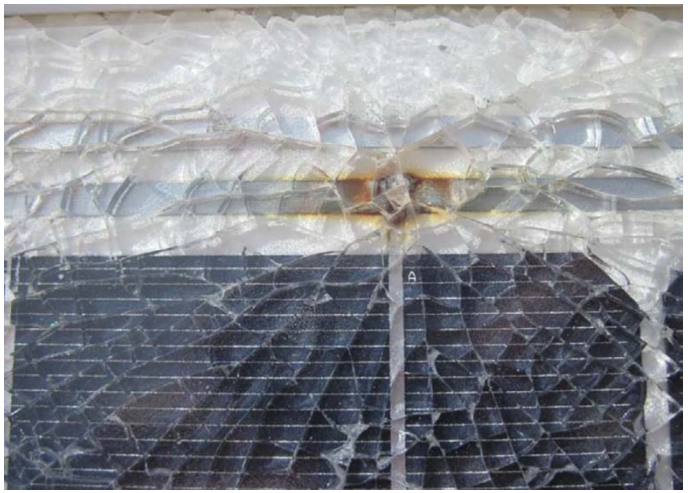
Hot Spot caused by crack in the cell



Source: "Hot Spot Evaluation of Photovoltaic Modules", Govindasamy (Mani) Tamizhmani and Samir Sharma, Photovoltaic Testing Laboratory (ASU-PTL)

Process Control – Electroluminescence (EL) scan on each module before releasing the product.

Hot Spot caused by poor solder joint



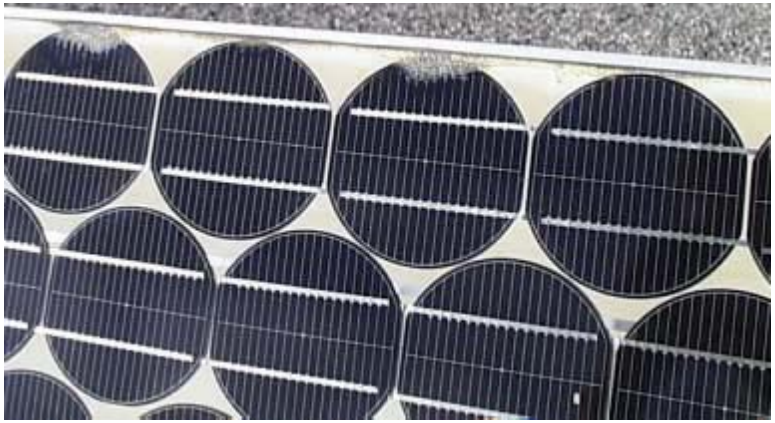
Source: "PV Module Arc Fault Modeling and Analysis", Jason Strauch, Sandia National Laboratories

Process Control – Certified Soldering Operator – recertified annually and inline test developed to test solder joint integrity.

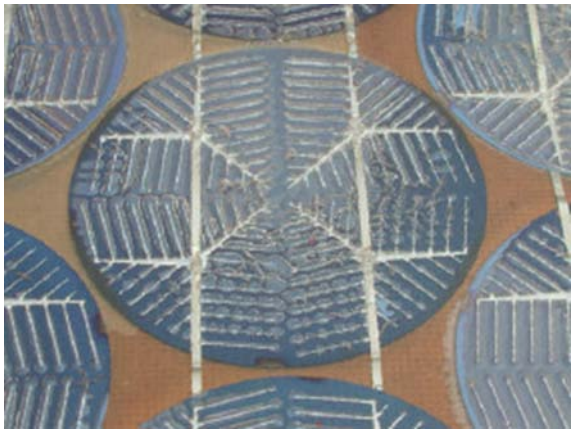
Lesson Learned: Control the critical processes or pay for it in the field.

Lessons Learned – Flat Panel PV

Moisture is your enemy



Source: "TISO 10 kW Array – Born on May 13, 1982", G. Travaglini[a], J. Bishop[b], Et al., [a]LEEE-TISO, Univeristy of Applied Sciences of Southern Switzerland, [b]ESTI, JRC, Ispra



Source: "Lifetime Performance of Crystalline Silicon PV Modules", Ewan D. Dunlap, European Commission, Joint Research Centre, Institute for Environment and Sustainability, Renewable Energies Unit

A change in Anti-reflective coating (ARC) caused an interaction between the encapsulant and the ARC which caused delamination in the field.

Lesson Learned: Understand paths of moisture ingress and interactions

Lessons Learned – Flat Panel PV

Design and Validate

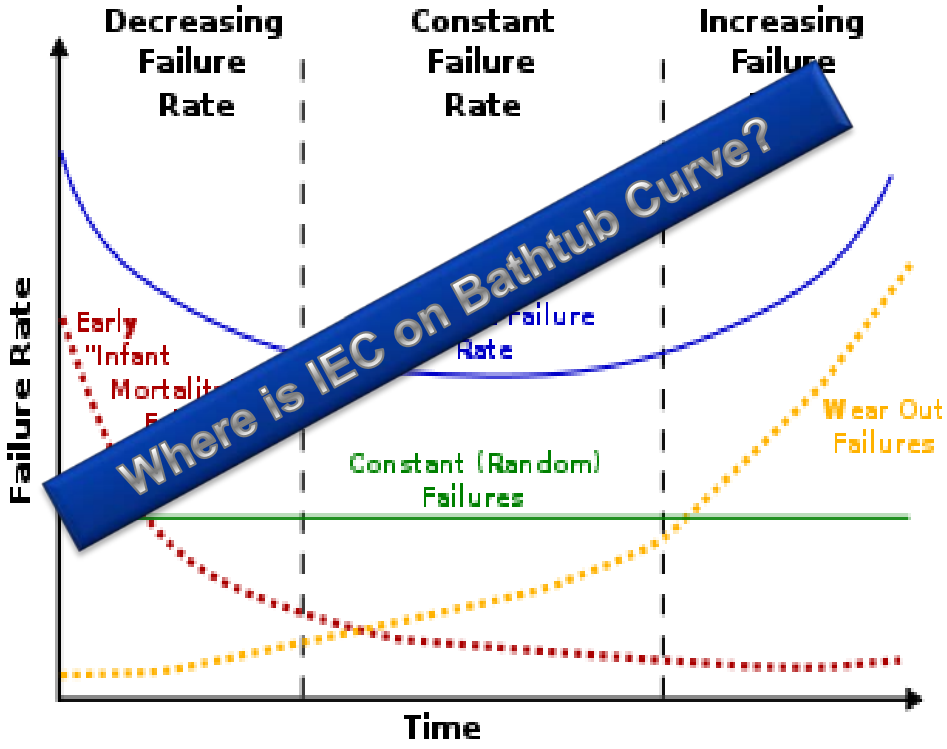
During standard product improvement cycle, a new design for a Junction Box was created. Initial verification showed great performance. Samples were summited to stress tests and were found to develop a wet insulation resistance failure. Failure analysis was conducted and root cause was determined. J-Box design was changed and passed wet insulation resistance test after the environmental stresses had been applied. No field problems were seen.

*Source: Kostal Junction box – **NOT ACTUAL J-Box used. Only for example***

Lesson Learned: Design and Validate – field returns are too late.

Lessons Learned – Flat Panel PV

Go Beyond IEC



$$k = A\,e^{-E_a/RT} = A\exp(-E_a/RT) \qquad (1)$$

$$\ln k = \ln A - \frac{E_a}{R}\left(\frac{1}{T}\right) \qquad (2)$$

$$\ln\left(\frac{k}{A}\right) = -\frac{E_a}{RT} \quad \text{or} \quad \ln\left(\frac{A}{k}\right) = \frac{E_a}{RT} \qquad (3)$$

$$\ln\frac{k_2}{k_1} = -\frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right) \qquad (4)$$

Failure mechanisms may not be exactly know but we do know several of the types of stress – humidity, temperature cycling and freezing. Testing to failure in these stresses help compare relative performance between design choices.

Lesson Learned: Stress until failing creates more information than stress alone

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Lessons Learned – Flat Panel PV

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Control the critical processes or pay for it in the field.

Understand paths of moisture ingress and interactions

Design and Validate – field returns are too late.

Stress until failing creates more information than stress alone